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A Study of Available Time for Engineering Undergraduates' Involvement in Co-curricular Activities

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Abstract

Despite the value of co-curricular activities, it is reported in the literature that engineering students are less likely to pursue co-curricular opportunities. This study is focused on developing a baseline model of the possible available time for engineering undergraduates to participate in co-curricular activities using two institutional data sources, the National Survey of Student Engagement (NSSE) and the class schedule data for all undergraduates for one semester. We simulated the weekly time commitments of students necessary to complete course work and other necessary daily activities. Based on this simulated data, we developed a distribution of the "residual time." This estimate provides a baseline for the amount of time available for students where co-curricular activities might be accommodated. This baseline can be used to inform a variety of stakeholders, including students, academic advisors, departmental curriculum planners, school administrators, and individuals responsible for staffing co-curricular facilities. In short, we see such analysis as an important input to a discussion that should occur between these stakeholders regarding how to balance and optimize curricular and co-curricular learning. While this baseline analysis can be a useful starting point, we discuss a number of relevant blind spots that need further study.

1.0 Introduction

Most institutions of higher education encourage their students to pursue co-curricular opportunities to ensure a more holistic educational experience. Co-curricular activities that include learning opportunities like student clubs, internships, undergraduate research, and service learning are recognized as "high-impact" experiences [1]. While institutions may include high-impact experiences as part of the curriculum, they can also be accommodated through co-curricular programming models. For example, at the University at Buffalo, the School of Engineering and Applied Sciences has an Engineering Intramurals program that brings together students from multiple engineering disciplines to work on problems from industry, community groups, and technical competitions.

While co-curricular activities can include a wide array of activities that occur outside of the curriculum, the interest in this work is on co-curricular activities that would be relevant to the profession. These would be categorized as experiences and activities that complement coursework in the major without being directly tied to a specific course (though could provide academic credit) [2]. For example, participation in a student engineering club focused on professional development activities or a technical competition provides learning opportunities that are more directly applicable to the profession, than would a co-curricular like an intramural sport. Such co-curricular activities enable students to supplement their learning through experiences that make students more competitive candidates for employment [3]. They foster development of technical and professional competencies in ways that can be difficult, if not impossible, to replicate authentically in a classroom, such as application of digital tools and regulatory codes in solving open and ill-structured problems over an extended period of time.

Despite the broadly recognized value of co-curricular experiences there is a lack of evidence that this value extends to engineering education, where the mandated curriculum can be overwhelming for students leading to a lack of time for co-curricular engagement [4]. Despite a range of cognitive and affective benefits, engineering students are less likely to pursue co-curricular opportunities [2]. These findings raise a fundamental question about co-curricular involvement, namely, how much time is necessary for *meaningful* co-curricular engagement? Recognizing that available time is a major hindrance to co-curricular participation, this study considered two questions important to understanding the potential for meaningful co-curricular engagement for individual students. First, *how many hours per week might students have available for participation in co-curricular activities*? Second, *when and how long are the available unscheduled times in a students' weekly schedule*?

These questions are asked from the perspective of the experiential learning program in the School of Engineering and Applied Sciences at the University at Buffalo, which is focused on developing and promoting co-curricular experiences to engineering undergraduates as a complement to the classroom. In the face of the challenges for engineering undergraduate participation reported in the literature [2], [4] we sought to estimate the time distribution for a variety of student activities and to identify key time clusters where co-curriculars might be accommodated. Exploring these questions is important to informing the design, facilitation, and institutional policies that directly and indirectly play a role in students' ability to pursue co-curriculars.

To answer our research questions, we used two institutional data sources - the spring semester schedules for engineering undergraduate students and the National Survey of Student Engagement data for the corresponding semester [5]. Using these data sources, we developed a model to simulate the available time that students potentially have for co-curricular engagement - so called "residual time" after students complete course work and attend to other commitments (e.g. off-campus work). Further, we consider when that residual time might be used by analyzing the gaps in student schedules. Finally, we consider how that residual time breaks down across demographic groups.

This paper is organized as follows. In the next section, we provide a brief literature review to position this work in the literature on co-curricular involvement for engineering undergraduates. In Section 3 we describe the methodology that underlies the simulation modeling. Results of the simulation are reported in Section 4. The manuscript concludes with a discussion of implications and possible future directions of this work in Section 5.

2.0 Literature Review

Co-curricular activities are among, or include elements of, high-impact educational practices that can significantly benefit students by increasing learning outcomes and persistence [1]. The benefits of co-curriculars emerge where learning opportunities require students to be engaged and invested voluntarily, especially when interacting with faculty and peers around important topics, engaging with diverse groups, and transferring learning from one setting to another [1]. Further, students from historically underrepresented groups benefit more from high impact practices that can be found in co-curricular experiences than their majority peers in terms of performance and persistence [1].

A broad study of undergraduate student involvement in academic and co-curricular activities [6] found positive correlation between academic and co-curricular involvement on cognitive and affective growth. Further, the study authors argue that participation in co-curriculars need not take away from traditional, academic engagement. Instead a number of other intrapersonal and contextual factors should be considered (e.g. time management, working, instructor quality) if participation in co-curricular involvement is perceived as negatively impacting curricular engagements [6].

A range of benefits associated with a variety of co-curricular activities have been described in the literature. These include improved retention and persistence in the discipline, gains in cognitive skills, improvements in professional competencies, and positive impacts on affective aspects like motivation and self-efficacy.

For example, undergraduate research (UR) experiences are a well-researched topic, and includes both curriculum-integrated and co-curricular models. According to a consensus study from the National Academy of Sciences, Engineering, and Medicine, there is robust evidence demonstrating that involvement in undergraduate research improves retention within STEM fields, including for under-represented populations [7]. Carter et al. found that involvement in UR is a significant predictor of communication skills; students with such experiences report higher levels of communication skills compared to their non-UR peers [8]. A self-report survey of engineering alumni found that those who participated in a structured UR program reported greater enhancement of speaking skills, understanding scientific findings, and career goals when compared to their peers with no research experience [9]. Despite widely cited benefits related to development of professionally relevant skills and retention, the National Academies report notes that there remains a need for more systematic research into the outcomes of undergraduate research experiences in order to improve undergraduate training [7]. The report also highlights that much of the research findings are associated with 10-week summer programs (e.g. REU programs) and more research on in-semester research experiences is needed [7].

Engineering student clubs represent another common co-curricular mechanism in undergraduate engineering programs. Many of these clubs are associated with professional organizations - e.g. Society of Automotive Engineers (SAE), American Society of Civil Engineers (ASCE), Biomedical Engineering Society (BMES) - that promote professional development through technical project competitions, conferences, and networking events. However, the ways in which clubs help in professional formation and the specific forms of learning within clubs is poorly understood [10]. Hinkle and Koretsky investigated the experiences of three different student clubs and found three different sets of learning outcomes [10]. Those learning outcomes would all be considered valuable and included: creativity and experimentation in one club, deep technical experience and industry-aligned practices in another, and effective communication and consideration of social and cultural context in the third. The structure and activity of each club was fundamental to the learning that occurred [10]. Another study focused on the co-curricular experiences of African-American students reported gains in teamwork and reflective behavior through involvement in engineering clubs compared with their non-participating peers [11]. They also found that more engagement led to higher gains [11].

Other co-curriculars that are not necessarily limited to engineering, like makerspaces, have been shown to provide important educational benefits. Co-curricular activities, including non-engineering activities, that involve multidisciplinary design elements can facilitate development and appreciation for interdisciplinary competence and associated skills like teamwork and leadership that are critical to being an engineer [12], [13]. For under-represented minorities, co-curricular participation – especially non-engineering groups – has been shown to improve perceptions of design and communication skills among female students [14].

In the context of makerspaces, Torralba et al present a detailed case study on three different team experiences in a makerspace for students immersed in a design challenge and concluded that varying expertise, legitimate peripheral participation, and makerspace support structures can lead to significant, positive difference in the experiences of individual students [15]. They also concluded that the potential for attracting and retaining students from underrepresented groups, based on the experience of a female engineering student who transitioned from a beginner to expert in a single semester within the space, can be facilitated by strong legitimate peripheral participation and mentoring. However, they also note that additional research is necessary to determine if this will occur at scale. Hilton et al found significant differences in students self-reported design self-efficacy before and after time spent in a university makerspace [16]. Positive changes occurred in students even if their level of participation stayed low across the semester. This suggests that makerspaces may have large, positive impacts on students without extensive investment of student time, which should be an important factor when choosing a co-curricular activity. Similarly, Nagel et al report early results of an ongoing project related to learning in makerspaces and note findings related to 1) the learning students' value (technical over professional competencies), 2) learning through failure, 3) a preference for unstructured learning (creative development) rather than structured learning (documenting and reporting), and 4) lessons of trust and leadership in collaborative project work [17].

The literature referenced here is certainly not exhaustive but it does demonstrate that there are a range of potential benefits from co-curriculars. However, the literature also suggests two challenges to understanding and assessing the benefits of student involvement in co-curricular activities. First, the benefits are mixed and not generalizable across co-curricular activities or student populations. While some beneficial learning outcomes may be expected, others might not. For instance, while involvement in undergraduate engineering research has been found to have positive impacts on technical communication, other professional competencies like teamwork and leadership are not significantly affected [8]. In other cases, while some studies show that more co-curricular engagement leads to greater gains, there may be diminishing returns or even unintended downsides from over-involvement. For example, co-curricular engagement can have a positive impact on ethical decision-making and leadership, and can reinforce classroom learning [18], [19] but over-involvement (i.e., spending too much time on a co-curricular) can create academic pressures that lead to unethical behavior [18]. More generally, the types of co-curricular and extracurricular engagement selected by students and their level of engagement therein has been found to differ by gender and ethnicity and is not necessarily guided by the benefits found in the literature [20]. There are numerous factors that impact the benefits of co-curriculars that can vary greatly from one institution to another and require intentional support structures to maximize benefits [21]. This might explain why benefits for one group at one institution are not necessarily observed at another institution for the same type of co-curricular.

A second challenge is that the benefits that might be obtained from co-curricular activities is limited by the time available for students to participate. The demands of the engineering curriculum make it difficult for many students to pursue co-curriculars [2], [4], [20]. Lichtenstein et al. analyzed NSSE data from the early 2000s for multiple institutions to compare the experiences of engineering undergraduates with undergraduates from other majors. Among their findings, they noted that first-year and senior engineering students -- the populations surveyed by NSSE -- reported spending their time similarly to students in other majors except for significantly more time spent preparing for class and less time working for pay off campus [4]. This led them to a fundamental conclusion that “the engineering curriculum creates demands that force students to make choices between acquiring practical (and highly marketable) skills during college in exchange for missing out on various educationally enriching experiences.”

Based on this fundamental conclusion, Simmons et al. conducted a preliminary study to understand engineering students’ participation in “out-of-class” (co-curricular and extracurricular) activities from the students’ perspectives [20]. They focused their study on identifying and exploring in-depth the “top activities” that students reported engaging in and the level of that engagement. The study found that the top activities reported by engineering students include sports, job (with no distinction between engineering and non-engineering work), and design competition teams. Other types of activities that might contribute to more holistic "whole person" development -- e.g. music and dance, social groups like fraternities and sororities -- were top activities for a small percentage of participants. Further, the authors concluded that it is concerning to see "a comparative lack of engagement in co-curricular out-of-class activities," which further supports the sentiment that the engineering curriculum leaves little time for students to pursue co-curricular activities [20]. Interestingly, the level of engagement in activities was not associated with a specific amount of time as the authors found that students significantly vary in their perceptions of what it means to be "highly active," -- i.e. two students who indicate being "highly active" may have significant variation in their reported hours or activity in a given month.

This second issue -- an apparent lack of time for co-curricular participation -- may undermine the benefits of co-curricular engagement because students are not able to substantively explore co-curriculars to find the right fit or engage long enough to accumulate beneficial outcomes. For example, the NAS report that highlights the retention and graduation rate benefits of undergraduate research also notes that the included studies do not address issues related to initial interest or motivation [7]. It is reasonable to assume that finding the right co-curricular fit will require exploration of multiple co-curricular activities. Further, it may require a period of engagement - weeks or months - before a student can meaningfully assess their interest and motivation for persisting. Thus, the issue of available time becomes a critical consideration to the design and facilitation of co-curricular programming. This issue is the focus of this study and the methodology for exploring the issue is described in the next section.

3.0 Study Methodology

The purpose of this study is to use available institutional data to help us understand 1) the available time that students might have in their weekly schedule for co-curricular involvement, and 2) when and how long the available time slots are. The institutional data used in this study includes the National Survey of Student Engagement (NSSE) for the University at Buffalo and the semester schedules for all undergraduate students in the School of Engineering and Applied Sciences (SEAS). Anonymized datasets for the spring of 2017 were provided by the Office of Institutional Analysis (NSSE data, 619 engineering respondents (476 male, 143 female) from first- or senior year) and the SEAS Office of Undergraduate Education (schedule data of 5,455 engineering undergraduates).

3.1 Residual Time Simulation

Toward understanding the time that the typical student might have available for co-curricular activities we developed a simulation. The purpose of the simulation is to estimate the "residual time" remaining for a student. Residual time is defined as the time, in hours, remaining in a students weekday schedule after they have completed curricular activities (e.g. going to class) and other daily routines (e.g. sleeping, working). The underlying equation for residual time (RT) is shown in equation (1).

$$RT = 120\ (hours) - Class - Slp - Eat - Trv - Hwk - Wrk - Soc \qquad (1)$$

Since we only have schedule data for students (i.e. we do not know the associated activity times for the students represented in the schedule data), the simulation is used to create an artificial population representative of the actual student population. The steps of the simulation process are as follows and were used to generate a population of 10,000 students.

1. Initiate the creation of a simulated student by randomly selecting a schedule from the student schedule data.
2. Calculate the total hours spent in class based on the course schedule and associated credit hours. This value represents the *Class* variable in equation (1).
3. Randomly assign a value - i.e. the hours necessary for each activity - for the remaining activity types represented in equation (1).
4. Calculate the residual time for the student using equation (1).

Each activity represented in equation (1) is detailed below. Since we are developing a simulation model, and want to show possible ranges of available time based on student schedules and associate activities, each term has an associated probability distribution. Each distribution is provided here with an explanation of source.

- *120 (hours)*: Our focus is to estimate available time during weekdays as it relates to the schedule of normal campus operations; labs and other co-curricular resources (e.g. machine shop, support staff) are typically accessible Monday through Friday from 10am - 6pm. Therefore, the equation constant of 120 hours reflects the available time from Monday through Friday.
- *Slp*: This variable represents time allocated to sleep. According to the Bureau of Labor and Statistics (BLS) American Time Use Study (ATUS) [22] the average hours of sleep per night for individuals over the age of 15 is 8.8 hours with a standard deviation of 1.22 hours. This is represented as a normally distributed variable in the simulation N(8.8, 1.22).
- *Eat*: This variable represents time allocated to eating. According to the BLS ATUS the average time spent eating per day is 64 minutes (1.07 hours) with a standard deviation of 50.9 minutes (0.85 hours). This is represented as a normally distributed variable in the simulation N(1.07, 0.85).
- *Class*: This variable represents the time spent in class for an individual student. The class time is determined for each simulated student based on the course schedule data.
- *Trv*: This variable represents the weekly commute time for students and has a corresponding variable in the NSSE survey, commute time. In the NSSE survey, commute time represents the time commuting to and from campus and does not account for other time spent traveling. In completing the NSSE survey students have nine response options 1 (0 hours per week), 2 (1-5), 3, (6-10), 4 (11-15), 5 (16-20), 6 (21-25 hours), 7 (26-30), 8 (more than 30). Since the

survey data are associated with ranges of time, we used the median number of the range. For example, if a student chose the range of 1-5 hours for commute time, they would be assigned a commute time of 3 hours. Using this approach for each of the 650 respondents we were able to find an (assumed) normal distribution for the commute time with a mean of 4.99 hours and standard deviation of 5.65 hours: N(4.99, 5.65).

- *Hwk*: This variable represents the time students spend preparing for class - i.e. doing homework, reading, and studying. This variable maps to the NSSE variable of "preparing for class" for which students have the same nine response options as for commute time. We simulated homework time as a function of the number of credit hours that a student was taking. Since the NSSE data reports the number of credit hours that a student is taking along with the time spent preparing for class (in ranges) we calculated the homework time per credit hour for each NSSE entry. This led to a normal distribution with a mean of 1.25 hours per credit hour and a standard deviation of 0.93, which was used in the simulation N(1.25, 0.93).
- *Wrk*: This variable represents the time students spend working. In the NSSE data, there are two separate variables that correspond to this variable, time working on-campus for pay and time working off-campus for pay. We aggregated this data into a single variable and followed the same process as that described for the *Trv* variable to create a normal probability distribution for the simulation: N(4.94, 8.57).
- *Soc*: This variable represents the time students spend socializing and relaxing and is directly reported in the NSSE survey as relaxing. We followed the same process as that described for the *Trv* variable to create a normal distribution for the simulation: N(12.95, 8.53).

3.2 Open Schedule Analysis

Toward understanding the duration of available openings in student schedules -- the amount of time students have between classes that might be used for co-curricular activities -- we analyzed the schedule data. Using Python we created a script to:

- Read through the schedule data for each student for each day of the week. Note, if a student had a day with no class we did not count that day. We made this decision because our institution has a high number of commuters and they do not necessarily come to campus on days when they do not have classes. We wanted to focus our understanding on the times available when we know students will be on campus. Further, the majority of undergraduate students will have classes everyday of the week.
- For the hours of 9am - 6pm we identified all the open time slots -- i.e. times when students were not scheduled for class -- and stored this information for each student. The duration of each opening in minutes was calculated and stored. We used 9am - 6pm because it coincides with the open times for various labs and associated support staff that might be used as part of co-curriculars (e.g. machine shop).

An example student schedule is shown in Table 1 with the resulting openings and duration calculations shown in Table 2. This approach was applied to all 5,455 student schedules.

Table 1. *Example student schedule*

Class	Days	Start Time	End Time
A	Mon, Wed, Fri	11:00 am	11:50 am
B	Mon, Wed, Fri	10:00 am	10:50 am
C	Tue	1:00 pm	1:50 pm
D	Mon, Wed, Fri	3:00 pm	3:50 pm
E	Tue	8:00 am	9:50 pm
F	Tue, Thu	11:00 am	12:20 pm

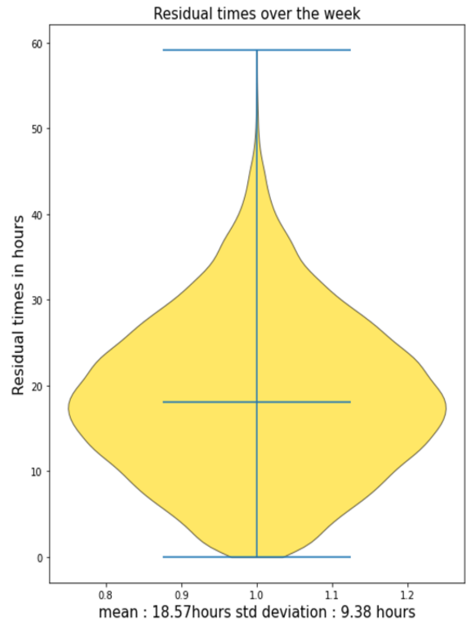
Table 2. *Schedule openings and calculated durations for the student schedule of Table 1*

Day	Schedule Opening	Duration (min)	Schedule Opening	Duration (min)	Schedule Opening	Duration (min)	Schedule Opening	Duration (min)
Mon	('9:00', '10:0')	60	('10:50', '11:00')	10	('11:50', '15:00')	190	('15:50', '18:00')	130
Tue	('9:50', '11:00')	70	('12:20', '13:00')	40	('13:50', '18:00')	250		
Wed	('9:00', '10:00')	60	('10:50', '11:00')	10	('11:50', '15:00')	190	('15:50', '18:00')	130
Thu	('9:00', '11:00')	120	('12:20', '18:00')	340				
Fri	('9:00', '10:00')	60	('10:50', '11:00')	10	('11:50', '15:00')	190	('15:50', '18:00')	130

4.0 Results

4.1 Residual Time

A violin plot with embedded box plot and summary statistics for the residual time simulation is shown in Figure 1. Based on the simulation the average student would be expected to have 19 hours of residual time in their weekday schedule, approximately four hours per day. While we are reporting mean and standard deviation, the distribution is not a true normal because of the truncation at zero.



Residual Time (hours)	
mean	19
standard deviation	9.5
min	0
25%	12.2
50%	18.6
75%	25.4
max	59.5

Figure 1. *Plot of residual times for engineering undergraduates based on simulation*

4.2 Schedule Opening Durations

Figure 2 shows box plot results from the open schedule analysis with summary statistics in Table 3. The results have been broken down into groupings for students based on ranges of credit hours. Students with nine or less credit hours have, on average, at least one opening in their schedule that is 3.8 hours long. As would be expected, as credit hours increase, the average duration of schedule openings shrink to 2.8 hours for 10-12 credit hours, 2.25 hours for 13-15 credit hours, and 1.9 hours for students with more than 15 credit hours.

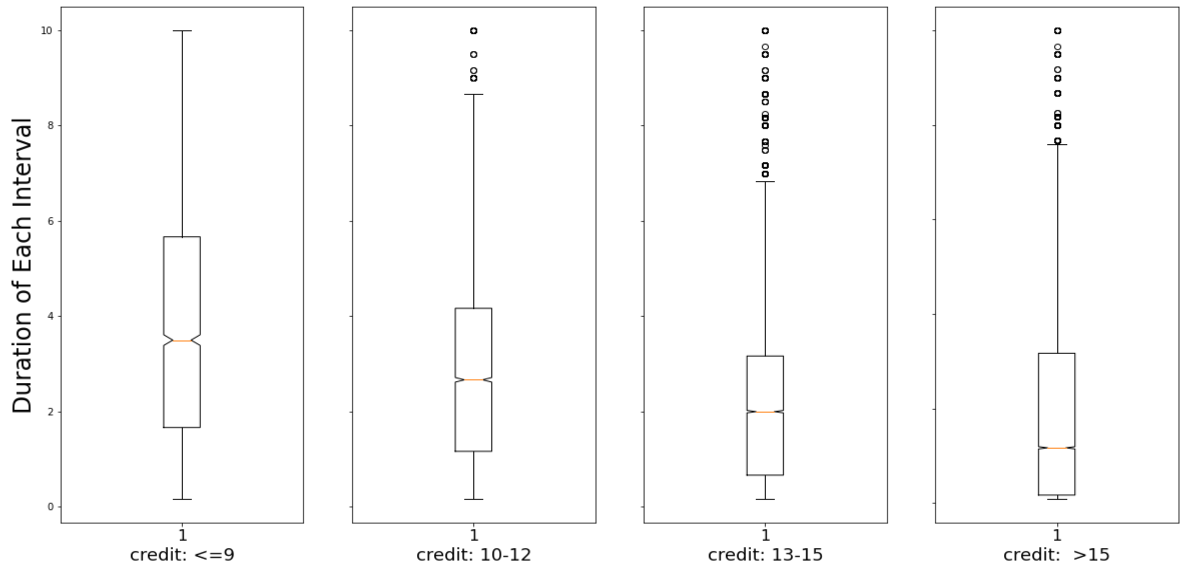


Figure 2. *Box plot of schedule opening durations in hours for students based on credit hours*

Table 3. *Summary statistics for schedule opening durations in hours*

	<=9 Credits	**10-12 Credits**	**13-15 Credits**	**>15 Credits**
No of students	923	1002	1671	1859
mean	3.8	2.9	2.3	1.9
stdev	2.6	2.6	2.0	1.8
min	0.17	0. 17	0. 17	0. 17
25%	1.67	1.17	0.67	0.17
50%	3.5	2.67	2	1.17
75%	5.67	4.17	3.17	3.17
max	10	10	10	10

5.0 Discussion of Implications and Future Work

From these results, we can answer the research questions -- *how many hours per week might students have available for participation in co-curricular activities*? and *when and how long are the available unscheduled times in a students' weekly schedule*? -- to say that the "typical" engineering undergraduate at our institution has on the order of 12-25 total hours of residual time during the weekdays with at least one 2-hour long window between 9am and 6pm. The results provide us with some insight into the *potential* time available for students to engage in co-curricular activities.

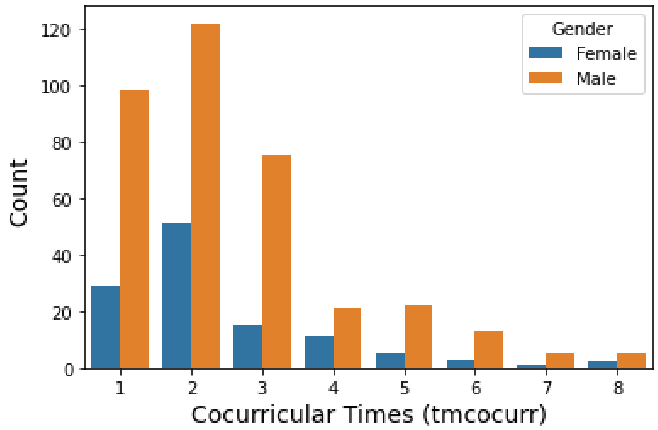


Figure 3. *Time spent on co-curriculars as reported by students in the NSSE by gender. This represents 117 females and 361 males who provided responses for this survey item. Response corresponds to a range (1 = 0 hours, 2 = 1-5 hours, 3 = 6-10, 4 = 11-15, 5 = 16-20, 6 = 21-25, 7 = 26-30, 8 = over 30)*

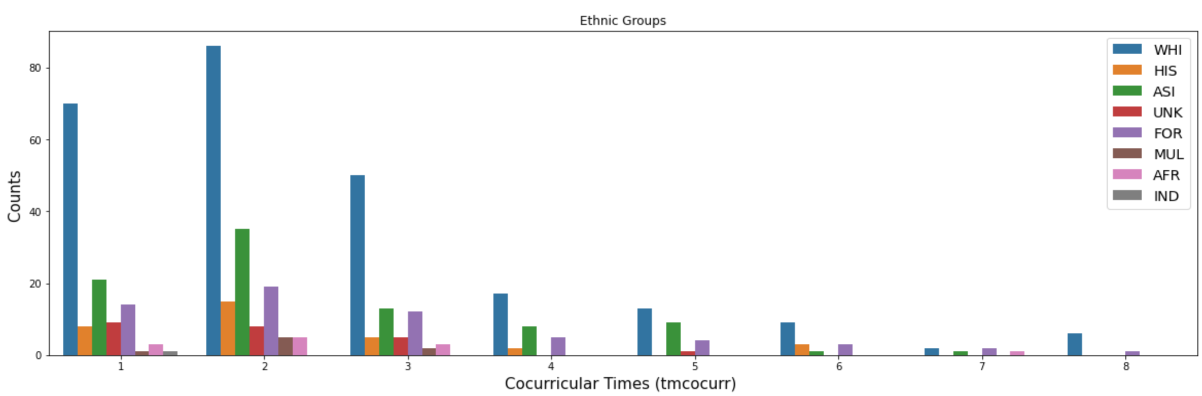


Figure 4. *Time spent on co-curriculars as reported by students in the NSSE by ethnicity (WHI = White - 253 students, HIS = Hispanic - 33, ASI = Asian - 88, UNK = Unknown - 23, FOR = International - 60, MUL = multiracial - 8, AFR = African American - 12, IND = Native American - 1)*

So, how is this potential time leveraged for co-curricular involvement? Figures 3 and 4 show the time that students reported spending on co-curricular activities in the NSSE survey, reported by gender and ethnicity, respectively. From Figure 3, we see that the majority of students, male (61%) and female (68%), reported spending 1-5 hours per week on co-curricular activities, or no time at all. Figure 4 shows a similar result based on ethnicity.

The residual time simulation results of Figure 1 suggest that a majority of students would have on the order of 12-25 hours of residual time during the *weekdays* (i.e. there is potentially more time available if we consider weekends). Yet, student involvement in co-curriculars is typically reported to fill only a fraction of that time, with many students reporting no time spent on co-curriculars (Figures 3 and 4). The generally low participation in co-curriculars reported by our engineering undergraduates is consistent with findings across institutions reported elsewhere [4].

Based on the apparent difference in potential time for co-curricular activities and the actual time spent on co-curriculars as reported by students, a number of questions arise. We consider three here that we believe are worthy of deeper investigation.

Question 1: Is this a marketing problem? Given the resources that institutions of higher education invest in growing and supporting co-curriculars and the importance of co-curriculars as expressed by industry, you might expect that students would spend as much available time as possible on co-curriculars. As this does not appear to be the case, we wonder if one issue is related to the marketing of co-curriculars in terms of their value in helping students to develop a range of skills relevant to the profession and their personal growth.

Education research rooted in expectancy value theory (EVT) demonstrates that the motivational factors and interactions that drive student engagement and persistence in activities are complex [23–26]. This research has provided significant insight into how students perceive their abilities and values and how those perceptions influence educational choice. Eccles and Wigfield found that adolescents can distinguish between expectancy for success and values of tasks [27]. This capacity to differentiate suggests that if we understand why students perceive an expectation for success in a co-curricular activity or why a co-curricular activity is perceived to be valuable then we can guide students into choosing optimal co-curricular learning opportunities.

Jones et al [28] investigated the motivations of first year engineering students through the lens of EVT and found that understanding student motivation, as it relates to education and career plans, necessitates use of multiple constructs related to expectancy and value. Additionally, they found that while both men and women have similar levels of value-related beliefs, both reported “enjoying engineering less and viewed it as less important and useful” by the end of the first year [28]. Similar declines in motivational trajectories among engineering students in the first two years have also been reported by Robinson et al [29]. Guiding students to the right co-curricular activity should directly reverse this type of decline by introducing activities that connect engineering to what students value and expect to succeed in doing.

But we cannot provide all students the same guidelines or advice for choosing co-curriculars. There are differences among genders and ethnicities pertaining to motivation constructs [24]. For instance, men and women may hold different expectancy beliefs for different activities [28], [30]–[32]. Female students have also been found to be more likely to experience a low attainment value as compared to their male peers in engineering education [33]. The relative lack of women in engineering and other STEM majors has been attributed, in part, to these differences in beliefs and values and educators' inability to act on those differences [30], [34].

Research that more deeply explores how students ascribe value to and what they learn through co-curriculars would help to inform a more precise marketing of co-curriculars to different student groups. Such research would help to inform student choice and perhaps improve motivation and persistence in co-curriculars.

Question 2: Do we know enough about how students spend their time? While the results provide some insight regarding what we might expect in terms of student availability for co-curriculars, the study (and the data it is based upon) provide little insight on how students use their available time. For instance, there are other forms of travel time than just commuting to and from campus, which does not appear to be accounted for in the NSSE data.

Additionally, we would anticipate some form of time "leakage" associated with transitioning between activities. For example, the time spent traveling from one class to another is necessary time that may not be accounted for in the available data. Another example may be the "ramp-up" and "ramp-down" time associated with various activities, including co-curriculars. Ramp-up is the time required to set up before becoming deeply engaged in the activity and ramp-down is the time that might be required to clean up and also to reflect on learning. If these ramp-up and ramp-down requirements are equivalent to the time spent engaged in the activity, it may discourage persistence in some activities; especially voluntary activities like co-curriculars.

Related to the issue of understanding student time use is the result that we found in the NSSE data for homework time. Based on our institutional data, we found that students spend, on average, 1.25 hours per credit hour on class preparation each week. Given the sentiment found in the literature that engineering students may be overwhelmed by the demands of the curriculum, we expected a higher value. Especially when considering the heuristic that class preparation should be on the order of 2-3 hours per course credit hour [35], [36]. This result raises two questions. Could it be that students are under-estimating the time they spend preparing for class? Or is it possible that the intensity of engineering course work is mentally taxing and stressful to the point that students do not have the energy or interest for engagement with co-curriculars?

Research that tracks the ways in which students allocate their time throughout the week and the related stress would be valuable in developing a more precise understanding of the time use issue among engineering students. While there is significant research related to complementary issues, like self-regulation [37], [38], a cursory search for literature related to student time allocation on

Google scholar over the past decade yielded few results with a time study element (i.e. keeping a time journal [39]) beyond self-report and none specific to engineering students.

Question 3: How can institutions best support co-curricular engagement? This question is important in so much as the academic institutions can influence the design and implementation of some co-curricular activities. Results of this study can help to inform some of that decision making. For example, understanding the time available overall and the duration of openings in student schedules can inform the design of individual co-curricular learning activities, like learning how to use equipment in university makerspaces. However, many co-curricular activities, like technical competition projects, require collaboration among students and significant student scheduling conflicts during the day may make meeting infeasible. This leads to students meeting after normal class hours, but this may mean that support facilities (e.g. machine shops and makerspaces) are not available because they close when the staff leave. Consideration of schedules may be helpful to informing the available hours of support labs, but would require a strong relationship between those facilities and the support structures that facilitate co-curricular activities.

This baseline study should serve as a basis for a discussion among a variety of stakeholders, including students, academic advisors, departmental curriculum planners, school administrators, and individuals responsible for staffing co-curricular facilities. Institutional support of co-curricular experiences goes beyond scheduling considerations. As described by Lee and Matusovich, institutional support can include a range of services, programs, and activities that impact the undergraduate experience inside and outside of the classroom [21]. In developing a conceptual model for co-curricular support, they provide a framework for research on the undergraduate experience that can support: 1) consideration of individual differences important to retaining diverse students, 2) consideration of multiple facets of the student experience (academic, social, professional) which may be handled in isolation by different institutional units, and 3) evaluation and revision of student focused interventions. Adoption of such a framework to guide research, in combination with research on student motivation and time studies, would help in developing a more robust understanding of the undergraduate student experience, including the role of co-curriculars.

5.1 Conclusions and Future Work

The purpose of this study has been the consideration of two questions. First, *how many hours per week might students have available for participation in co-curricular activities*? Second, *when and how long are the available unscheduled times in a students' weekly schedule*? Using National Survey of Student Engagement and student schedule data for our institution we developed a simulation based approach to estimate the available time and to consider the duration of unscheduled times in student schedules. These estimates allowed for consideration of the difference between the potential available time for co-curricular engagement and the time actually reported by students.

Through this comparison we believe that there is opportunity for students to be more involved in co-curriculars, which may enhance their overall educational experience and better prepare them for life after school. Given the pervasive sentiment that co-curricular experiences are important and the relative lack of co-curricular involvement among engineering undergraduates we believe that this topic needs more research and greater collaboration within and across institutions. We hope to pursue this research on two fronts. First, we would like to partner with peer institutions to apply the methodology employed here for comparative purposes. Second, and ideally in collaboration with those peer institutions, we would like to pursue substantive research that addresses the three questions explored in the Discussion section.

5.2 Limitations

The purpose of this study is to provide an estimate of student availability for co-curriculars. The aim of the study is to support a broader discussion within the engineering education community. While we feel that the work has met that aim, there are three important limitations that affect the accuracy of our findings -- though we do not know to what extent. First, the activity times taken from the NSSE data are based on self-report data with no corroborating time study. Further, we made necessary assumptions to convert ranges of data to a single value in order to conduct the simulation. Second, the NSSE survey data reflects first- and senior year students. Therefore, we are assuming that these data also reflect the activity times of middle year students. Finally, as our estimate of available time is focused on weekdays, we assumed that the reported times for things like working, socializing, and class prep from the NSSE data are equally distributed over each day of the week. In reality we know this would not be the case but this simplifying assumption was necessary here.

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